LESSON FTR - 26

UNIVERSAL, A-C/D-C RECEIVERS

DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

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UNIVERSAL A-C/D-C RECEIVERS

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Our best friends and our worst enemies are our thoughts. A thought can do us more good than a doctor or a banker or a faithful friend. It can also do us more harm than a brick.

-- Dr. Frank Crane

AUTOMOBILE RECEIVERS

In the first models of automobile radio receivers, various circuit arrangements were used to make possible the operation of the existing types of 5 volt and 2.5 volt tubes, by means of the ordinary 6 volt auto battery. The results were not satisfactory as the filaments of those tubes requiring comparatively low current were too fragile, while those requiring larger currents placed a heavy drain on the battery.

To overcome these difficulties, a new series of tubes were developed with a heater designed for 6.3 volts at a current of .3 ampere. Several power tubes in this series require a higher value of current but in all of them, the required heater or filament current is low compared to the older types.

In addition to this economy of current, the heaters are of rugged construction and not at all critical, in respect to the voltage changes which occur in the average auto electrical system. Like auto type lamp bulbs, they will operate satisfactorily from 5.5 volts up to 8.5 volts.

The development of these tubes has eliminated all complicated filament circuits as it is now only necessary to connect the heaters in parallel across the supply without any series resistors, the same as is done in the usual a-c broadcast receiver used in the home. For the auto, the regular 6 volt car battery is the source and, for reasons we will explain later, the receiver connections are usually made directly at the battery terminals.

HIGH VOLTAGE SUPPLY

Although the 6.3 volt tubes have solved the problems of the filament and heater circuits, like other receivers, the auto radio requires a high voltage d-c supply for the plate and screen grid circuits of the tubes. In the older types of receivers, B batteries made up this high voltage supply and, although giving satisfactory and fairly economical service, had to be replaced periodically. This feature was objectionable to the average owner who, with his home receiver in mind, demanded an "All Electric" auto radio.

As you already know, by means of a transformer, it is a comparatively simple job to change the voltage of an a-c supply to almost any desired value but, in an auto, we have a low voltage d-c supply. As the usual form of transformer will not operate on direct current, various other methods have been developed.

VIBRATOR TYPES

As we just told you, it is easy to increase an AC voltage and the most popular method is to use a vibrator to help change the battery d-c to a-c, raise the a-c voltage by means of a transformer and then rectify it by means of a tube. The circuits of an arrangement of this type are shown in Figure 1 where you will find one Low Voltage Terminal grounded while the other connects to an r-f filter through a switch. (1)

Because some Auto Electrical Systems ground the battery positive and others the battery negative, it is customary to speak of the battery connections as "Hot A" and Ground. Thus, in Figure 1, the upper Low Voltage Terminal is "Hot A" and the lower one is "Ground". To simplify our explanations, we will consider the "Hot A" as positive but, the unit will operate equally well when the "Hot A" is negative. (2)

Starting at the "Hot A" terminal of Figure 1, there is a circuit through the switch and through the filament of the Rectifier tube to ground. Condenser C_4 connects directly across the filament and helps to keep out any electrical disturbances of the auto system.

The vibrator, shown at the left of the transformer "T", is made up of a magnet coil, a vibrating armature and two pairs of contacts. The armature and one end of the magnet winding are grounded on the vibrator frame.

From the switch "SW" there is another circuit through the radio frequency choke "RFC" and up to the center tap of the primary winding of the transformer, through the upper half of the winding, through the upper pair of vibrator contacts and armature to ground. Also a circuit from the center tap through the lower half of the primary and magnet winding to ground.

Resistances R_1 and R_2, across the contacts, have a value of about 200 ohms each, the current through them being negligible for this explanation. However, the magnet winding, with a relatively high resistance and large number of turns, holds the current in its circuit to a low value but produces sufficient magnetic flux to attract the armature, opening the upper pair and closing the lower pair of contacts.

With the upper contacts open, resistance R_1 is in series with the upper half of the transformer primary reducing the current to a negligible value. With the lower contacts closed there is a direct circuit from the center tap, through the lower half of the transformer primary and through the lower pair of contacts to ground. Notice also, closing the lower pair of contacts shorts out the magnet winding and resistance R_2.

Shorting the magnet winding reduces its current to zero, reduces the magnetic flux it sets up and allows the spring to pull the armature back to the position of Figure 1 when the action starts all over again.

As far as the transformer is concerned, when the upper contacts are closed there is current in the upper half of the primary and when the lower contacts are closed, there is current in the lower half. Then, because the center tap connects directly to the battery, the current in each half of the primary is in opposite directions, setting up magnetic flux of opposite polarity and inducing an alternating voltage in the secondary.

In other words, the action of the vibrator is to cause the steady direct current of the battery to keep changing in value and direction as it passes through the transformer primary. The changing primary current sets up a magnetic flux, with similar changes, which cuts the turns of the secondary and induces an alternating voltage. The value of this voltage, like that of ordinary transformers, will depend on the turn ratio between the primary and secondary.

As we explained in the earlier Lessons, when an inductive circuit, like the transformer primary, is suddenly opened, the magnetic flux collapses and, by self induction, induces a high voltage in a direction to try and maintain the current. Here, this action will take place as the contacts open and the induced voltage will be high enough to cause an arc between them.

Because arcing contacts wear away rapidly and become pitted, in Figure 1 we have the 200 ohm resistors, R_1 and R_2 connected across them. Then, when the contacts separate, the circuit is not opened but the 200 ohm resistance is placed in series, forming a path for the current caused by the self induction and reducing the arc.

The same general action takes place in the primary circuit of the auto ignition system but there you will find a condenser connected across the contacts. While the condenser absorbs the arc between the contacts, it also discharges rapidly and then charges in the opposite direction producing a few high frequency cycles.

The discharge action of the condenser causes a more rapid change of flux in the ignition coil thereby increasing the secondary voltage and improving the spark. In the circuit of Figure 1, however, the high frequency discharge of the condenser could cause noisy reception without greatly improving the action.

Although non-inductive resistors are connected across the vibrator contacts, the action is not perfect and some unwanted frequencies will appear in the secondary. To eliminate these, condenser C_1, usually with a capacity of about .02 mf, is connected across the entire secondary winding.

The tube is a full wave rectifier with circuits like those of the common type 80 but it has a cathode which is the positive or high potential terminal of the high voltage circuit, while the center tap of the secondary winding is the negative terminal.

The action in this secondary circuit is exactly the same as that explained for full wave rectifiers therefore we will not go into further detail. However, there is a rectified a-c voltage across the high voltage terminals of Figure 1 and the usual form of filter will be needed between the rectifier and plate circuits of the tubes of the receiver.

INVERTER - RECTIFIER

To further simplify the circuits and save the power required to operate a rectifier tube, the vibrator action has been extended on the general plan of Figure 2. Here you will find five pairs of contacts, the single pair at the left in the circuit of the vibrator magnet, the center double pair in the secondary circuit and the right hand double pair in the primary circuit.

With the armature in the position shown, there will be a circuit from the Hot A, through the switch and "RFC", through the magnet winding and single pair of contacts to ground.

As we explained for Figure 1, current in the magnet coil sets up a magnetic flux which pulls the armature down and separates the contacts. Under these conditions, the magnet coil circuit is completed to ground through the 50 ohm resistor R_1 which reduces the current and flux to a value low enough to allow the spring to pull the armature away from the core and close the contacts.

In Figure 2, the vibrator circuits are entirely separate and the armature will vibrate at a frequency which depends on the mechanical construction, spring tension and so on. However, as the armature vibrates, both double pairs of contacts will be opened and closed as explained for those of Figure 1.

The primary circuit of Figure 2 is similar to that of Figure 1 and the action is exactly the same. We do not show any resistance connected across the primary contacts because the

inductance of the primary winding is so low that some manufacturers do not install them.

Because the action in the primary circuit changes d-c to a-c, this part of the unit is often called an "Inverter" to distinguish it from the more common rectifier which changes a-c to d-c. However, as d-c is required, the secondary contacts must operate as a Rectifier and thus the complete unit is known as an "Inverter-Rectifier" or Synchronous Vibrator. 3.

To simplify our explanation, we want you to imagine that when the direction of primary current is up, through transformer T of Figure 2, the direction of the induced voltage is down through the secondary winding.

In the position shown, the path of the primary current will be from the Hot A, through the switch and RFC to the center tap, up through the top half of the primary, through the upper pair of contacts and through the armature to ground.

The secondary voltage, or current, passing down through its winding, has no circuit from the lower end, because the lower secondary contacts are open but, there is a circuit from the center tap to the "pos" high voltage terminal and through the circuits of the receiver to the "neg" or ground. The path is completed from ground, through the armature and upper pair of contacts to the upper end of the secondary.

Should it confuse you to follow the primary and secondary currents through the armature in opposite directions at the same time, you can think of the secondary circuit as being completed from ground through the battery, Hot A terminal, switch, RFC, upper half of the primary and upper primary contacts to the armature.

When the magnet pulls the armature down, all the upper pairs of contacts are opened while both pairs of lower contacts are closed and there is current down through the lower half of the primary. The direction of the secondary current is up and its path will be from the center tap to the high voltage "pos" terminal, through the receiver circuits to ground. From ground, the path is as previously traced except it passes through the lower pair of contacts to the lower end of the secondary.

The condensers, C_1 and C_2, connected across the secondary contacts, act to reduce the arc when the circuits are opened, but as both condensers are in series across the entire secondary winding, they also provide a filtering action as explained for C_1 of Figure 1.

While there are many mechanical variations in vibrator type high voltage supplies, electrically, they can all be roughly divided into the general classes of Figure 1 and 2. In both cases, you will find a filter in the low voltage or car battery supply circuit to keep electrical disturbances of the auto electrical system out of the receiver circuits. Although not shown, it is necessary to have the usual type of filter between the high voltage terminals and the circuits of the receiver.

As far as actual size is concerned, the units of Figures 1 and 2 are made in compact form, small enough to build into the receiver chassis. Although the general trend seems to be toward building the power supply, receiver chassis and speaker in one complete unit, you will still find many installations in which they are made up as separate units. However, the difference between the single and separate units is entirely mechanical, the electrical circuits remaining practically the same in all cases.

TYPICAL AUTO RECEIVER

To give you a more complete idea of the application of the power supplies shown in the circuits of Figures 1 and 2, for Figure 3 we have drawn the complete circuit of a typical superheterodyne automobile receiver. Then, in order that you may completely understand it, we are going to take each of the circuits and explain them separately.

HEATER CIRCUITS

In Figure 3, the "Hot A" terminal connects to the insulated post of the car battery while the "Gnd" terminal is usually connected directly to the frame of the car, which is the other terminal of the car battery. Tracing the heater circuits, from the "Hot A" terminal we go down through an r-f choke "Ch_2" to an arrow indicating a connection to all heaters. One side of each tube heater is grounded and therefore is connected directly across or in parallel to the car battery. Notice, there are no resistors of any kind, the heater circuits being as simple as those of the a-c home type of radio receiver.

Let us assume the heaters of tubes T_1, T_2, and T_3 each require a heater current of .3 ampere while tubes T_4 and T_5 require .4 ampere. The total heater current will then be .3 x 3 or .9 ampere plus .4 x 2 or .8 ampere which is 1.7 amperes.

In addition to the tube heaters, the field of the dynamic speaker also connects across the battery and, assuming a resistance of 4 ohms, draws a current of 6 ÷ 4 or about 1.5 amperes. Adding this to the value given above, the battery drain for heaters and field will be 1.7 + 1.5 or 3.2 amperes.

Suppose the power supply of this receiver develops 250 volts at 30 milliamperes which is equal to 250 x .03 or 7.5 watts. Whenever energy is changed from one form to another there is a loss and we will assume this power supply is approximately 50% efficient. On this basis, the output of 7.5 watts means an input of 7.5 x 2 or 15 watts which, at 6 volts, requires a current of 2.5 amperes. Adding this value to the current required for the heaters and speaker field, the total battery drain will be 2.5 + 3.2 or 5.7 amperes.

Figuring roughly, automobile lamps require about 1 watt per candle power and as the receiver of Figure 3 requires 5.7 amperes at 6 volts, for a total power of 5.7 times 6 or 34.2 watts, the drain on the battery is only slightly more than that required for a 32 candle power headlamp.

HIGH VOLTAGE CIRCUITS

The high voltage supply of the complete receiver is practically the same as that explained for Figure 1 and because of this, we will not repeat the action. Tracing the current path from the cathode of the rectifier tube, T_5, we go through the choke coil "CH" which has a low d-c resistance with a comparatively high inductance. Condenser C_{19}, between the input end of the choke and B- has a fairly high capacity, somewhere around 8 microfarads, and C_{18}, connected between the output end of CH and B- has a capacity of about the same value. The choke coil CH and these capacities make up an efficient condenser input filter which delivers practically humless direct current to the receiver proper.

From the output end of the choke, there is a circuit direct to the screen grid of the output tube T_4. Other circuits from this same point are through the load resistance R_8 to the plate of T_3, through primary L_6 of the 2nd i-f transformer to the plate of T_2 and through the primary L_4 of the 1st i-f transformer to the plate of T_1.

Also, below this connection to L_4 you will find a circuit through R_1 to the screen grids of T_1 and T_2 together with a circuit through L_3 to the anode grid of T_1. R_1 is of such a value that, with normal currents in these circuits, there will be a voltage drop across it of such value as to allow proper voltages on the screens of T_1 and T_2 and the anode grid of T_1. The condenser, C_{10}, with a capacity of approximately .1 mfd, forms a low resistance path for r-f frequencies, thus preventing any unwanted coupling between screens and other circuits connected to the same supply.

The plate of the output tube operates at a high voltage and obtains this from the input end of the choke, CH, through the primary of the output transformer, T_o. The condenser C16, connected from the plate of T4 to ground attenuates some of the higher frequencies and thus, in effect, acts as a fixed tone control.

GRID VOLTAGES

Like most home radios, it is quite common practice to bias the grids of the tubes in an auto receiver by a combination of resistance and capacitance in their cathode circuits. However, in Figure 3, the bias voltages are obtained by a little different arrangement.

Tracing the circuit you will notice that the cathodes of T1, T2 and T4 are connected directly to ground. Then, the input grids of T1 and T2 are connected to R2 and from there to ground, through R3 and R6, while the control grid of T4 connects to ground through its load R9 and resistances R4, R5 and R6.

Now, as the cathodes of T1, T2 and T4 are grounded, in order for their current to return to B-, it must pass through the resistances R6, R5 and R4. Also, the cathode of T3 is connected between R5 and R6 and so its current must pass through R5 and R4 to reach B-.

Here is the point. In order to reach B-, the current of these tubes must pass through a resistance network and therefore, we can say that ground is positive in respect to B- or, in order words, any voltage drop across resistances R4, R5 and R6 is negative in respect to ground.

As the cathodes, or reference points of T1 and T2 are grounded, and their input grids connected to the negative end of R6 through R2 and R3, these tubes receive their initial bias voltage by the drop across R6. The cathode of T3 connects between R5 and R6 while the control grid of the triode section connects between R4 and R5, through its grid load R7, and therefore obtains its bias voltage from the drop across R5.

The cathode of T4 is connected directly to ground while the control grid is connected to B- through its load R9. With these connections, there is a difference of potential between the grid and cathode caused by a the total drop across resistances R4, R5 and R6 and, as this is negative in respect to the cathode, which is grounded, the necessary bias is obtained. Condenser C17 is connected directly across the bias resistors R4, R5 and R6, and serves to provide a more uniform d-c potential.

DUO-DIODE-TRIODE 1

The circuits and action of the tube T3, which is a duo-diode-triode type, are a little harder to follow because it acts as the second detector, automatic volume control and first audio amplifier.

The signal voltage appears across the tuned secondary, L7-C12, as the modulation of the intermediate frequency. The upper end of this circuit connects to both diode plates, which act as a half wave rectifier, and continues through the cathode, the potentiometer R3 and then back to the lower end of the tuned circuit.

Thus, the signal voltage, caused by the rectified current, will appear across R3 and we can consider it as the source of the audio signals. The direction of the rectified signal current will be from the plates through the tube to the cathode and back to the lower end of the tuned circuit through R3. Thus, an increase of signal voltage will cause more rectified signal current and make the lower end of the tuned circuit more negative in respect to ground.

In our former explanations we told you the input grid circuits of both T1 and T2 were connected to this same point and thus, an increase of signal strength will increase the negative grid voltage, thus reducing their amplification, providing avc as previously explained.

Considering R3 as the audio signal source, the movable arm is connected to the control grid of the triode section of T3, through the coupling condenser C14 and thus the signal voltage will appear across the grid load R7 and be impressed on the grid. By varying the position of the arm of R3, any amount of the signal voltage can be impressed on the grid of T3 and thus R3 acts as the manual volume control.

Under these conditions, the avc action tends to maintain a constant signal voltage across R3 and by adjusting the arm, any part of it may be applied to the grid of the triode section. In other words, the desired level is obtained by adjusting the manual volume control and the automatic action tends to maintain it.

SIGNAL CIRCUITS

Now that we have explained the various d-c circuits and part of the signal action of Figure 3, we are going to start with the antenna and follow the path of the signal through to the speaker. The modulated carrier wave cutting the antenna will

induce a voltage across the series combination of C1 and the lower end of the antenna coil L1. This coil, L1, acts as an auto-transformer with the part below the tap being the primary and the entire winding the secondary.

Thus, with current in the primary a larger voltage will appear in the secondary. Tuning condenser C3, with its trimmer C2, connected across the secondary in series with the blocking condenser C4, allows the circuit to be tuned, thus increasing the voltage of the resonant frequencies.

The exact purpose and action of the condenser in the position of C4 seems to be confusing, therefore an explanation will be of benefit. In the common types of tuning condensers, the rotors of all the sections are grounded, making it necessary to ground one end of the coil which the condenser connects across. However, the coil is also in the grid circuit and a direct ground means a grounded grid return. For the older circuits, this is a satisfactory arrangement but, when automatic volume control is used, the grid circuit cannot be grounded until it passes through various other resistances.

As far as the tuned secondary of L1, Figure 3 is concerned, condensers C3 and C4 are in series across the winding. You already know that the total capacity of two condensers in series is equal to the product of their capacities divided by their sum. Here, assuming C3 has a capacity of .00035 mfd, and C4 a capacity of .05 mfd, connected in series their total capacity is .0003475 mfd. Thus, for tuning, C4 has caused a change of but .7 of 1% in total capacity.

This small change can easily be compensated for by adjusting the trimmer condenser and, from a practical standpoint, the addition of C4 does not change the tuning, conditions remaining the same as if the coil were actually grounded.

However, grid bias is a d-c voltage and the presence of C4 effectively insulates the coil from ground, as far as d-c voltages are concerned, allowing the grid return to be carried through the desired resistances before being grounded.

Getting back to the signal, the voltage across the tuned circuit of L1- C3 is impressed on the input grid of T1 and mixed with the local oscillator frequency so as to form the modulated i-f frequency which appears across the tuned circuit L4-C8 that makes up the primary of the 1st i-f transformer.

The local oscillator is made up of the primary coil L3, inductively coupled to L2, and connected to the anode grid of T1. The oscillator control grid is connected to the tuned circuit

composed of L_2 in series with C_7 and the combination in parallel with the oscillator tuning condenser C_6, the trimmer C_5 and resistor R. Condensers C_5 and C_7 are really verniers on the main condenser C_6 and are adjusted so that the beat frequency between the carrier and local oscillator is the same as that to which the i-f transformers are tuned. Then to maintain this same i-f frequency over the entire broadcast band, the rotors of condensers C_3 and C_6 are mechanically ganged and turn on one shaft. The resistance R is used to connect the grid to ground so that oscillations may be obtained.

With the i-f signal in the primary of the 1st i-f transformer, a voltage of like frequency will be induced in the secondary L_5 which is tuned by condenser C_9. This tuned circuit impresses the signal on the control grid of T_2, in the plate circuit of which is the primary of the 2nd i-f transformer, L_6 tuned by condenser C_{11}.

The secondary of this transformer, coil L_7, is tuned by C_{12} and the signal voltage is impressed on the diode plates of T_3, which act as a rectifier and cause the audio signal to appear across R_3. Then, as previously explained, the desired part of the audio voltage is impressed on the triode grid of T_3.

The rectified signal, or audio voltage, is carried over from the plate of T_3 to the grid circuit of T_4 through the coupling condenser C_{15}. Changes of plate current in the output tube, T_4, cause changes of voltage across the primary of the output transformer T_O, the secondary of which connects to the voice coil of the speaker.

Checking back, on the more common plain, the tube, T_1, acts as an oscillator and first detector, or mixer, T_2 as an intermediate frequency amplifier, T_3 as a second detector, avc and 1st audio amplifier, T_4 as a power output and T_5 as a full wave rectifier.

While there are an almost endless variety of makes and models of auto radios, the circuits of Figure 3 give the fundamental principles of all types and if you fully understand them, you will not have any difficulty. As examples of variations of Figure 3, you may find receivers of this type with an r-f stage or an additional audio stage. Also, the output tubes may be connected in push-pull and the power supply may incorporate an "inverter-rectifier" instead of a tube. However, this should give you no particular difficulty because these and similar circuits have been completely explained.

UNIVERSAL RECEIVERS

The development of smaller and smaller midget or "Personal" Radio receivers has led the designers to simplify their circuits and eliminate all parts possible. Because of their small size and weight, receivers of this type are readily portable and therefore it is desirable that they operate on any lighting circuit, d-c or a-c and, in some cases, be arranged for battery operation as well.

For the rest of the Lesson therefore, we want to explain the common a-c/d-c type of Radio Receiver which usually operates on any 110-120 volt lighting circuit. While our examples are Radio receivers, the same general plan is used for public address amplifiers and other similar equipment.

SERIES FILAMENT CIRCUITS

Looking through the tube tables of an earlier Lesson, you will find that the filaments, or heaters, operate at comparatively low voltage and high current. Therefore, it is easy to see that, with a high voltage supply, it will be most economical to operate a number of heaters by connecting them in series.

As you already know, the voltage across a series circuit is equal to the sum of the voltage drops across the parts connected in series but, at any instant, the current is the same in all parts of the circuit. Because of these conditions, it is practical to connect heaters, of various voltages, in series, provided they require equal current. 5

Going back to the tube table again, you will find a wide variety of tube types, the heaters of which require .3 or .15 ampere of current for proper operation. Some of these were developed particularly for auto receivers and while the heaters are rated at 6.3 volts, their construction is rugged and they will operate satisfactorily from 6 to 8 volts. Other types have heaters rated at 12.6 volts, 25 volts, 50 volts, 70 volts and 117 volts.

Back in the earlier Lessons, we told you that alternating current was compared with direct current by its heating effect and therefore .3 ampere, either a-c or d-c will provide equal heat. Also, you will notice that all of these tubes are of the cathode type which makes the heater circuits independent of the signal circuits. Thus, there will be a minimum of hum when a-c is used to operate the heaters.

With these facts in mind, we want you to look at the circuit of Figure 4 which is a four tube Universal type Radio Receiver

containing an r-f amplifier tube, detector tube, an a-f amplifier tube and a rectifier tube.

To trace the heater circuit, we will start at the lower "110 volt supply" wire, and follow the path of the current through the switch, resistance "R_2", and the heaters of the rectifier, the a-f tube, the r-f tube and the detector. One side of the detector heater connects to the common return, which you can think of as the metal chassis, and following this return to the right, we come down and then left, to the upper "110 volt supply" wire.

To make a definite example, we will assume the following type tubes. 6K7G - r-f, 6J7G - det., 25A6G - a-f and 12Z3 rectifier. Checking back in the tube table you will find the following heater ratings.

Tube	Volts	Amps.
6K7G	6.3	.3
6J7G	6.3	.3
25A6G	25.0	.3
12Z3	12.6	.3

Notice here, the current is the same in all cases and, connected in series, the total drop across the four tubes will be equal to $6.3 + 6.3 + 25.0 + 12.6 = 50.2$ volts. Resistance R_2 is also in series and, following common practice, if we consider the supply as 117 volts, the drop across R_2 must be $117 - 50.2 = 66.8$ volts.

Knowing the values of current and voltage, we substitute in Ohm's Law and find R_2 requires a value of 66.8 volts divided by .3 amps or 222.7 ohms. The tube heaters, with a total drop of 50.2 volts at .3 amp have a total resistance of 50.2 divided by .3 or 167.3 ohms.

The complete filament or heater circuit therefore has a total resistance of $222.7 + 167.3 = 390$ ohms which, at 117 volts, allows a current of .3 ampere.

Going back to the earlier Lessons, you will remember that electrical power, in Watts, is equal to volts times amperes or amperes squared times ohms. Here, with 117 volts and .3 amp, the power in the entire circuit will be $117 \times .3 = 35.1$ watts. For the tube heaters only, 50.2 volts x .3 amp. = 15.06 watts and, for R_2 only, 66.8 volts x .3 amp = 20.04 watts.

We mention these values to bring out the fact that the power in R_2 is greater than that in all the tube heaters. As this

power is dissipated in the form of heat, R_2 will become quite warm, if not hot, when the receiver is in operation.

To keep this heat out of the receiver chassis and also to provide better radiation, the resistor R_2 may be located inside the supply cord between the receiver and attachment plug. This arrangement is known as a "Line Cord" and can be purchased complete with resistance values from 135 to 360 ohms. 6

From a practical standpoint, cords of this type become noticeably warm during normal operation and therefore, a hot cord is not an indication of trouble. Should it become necessary to replace the attachment plug or make other repairs, the cord must not be shortened as this will reduce the value of resistance and allow the tube heaters to operate at voltages high enough to shorten their life.

Resistances used for the purpose of R_2, Figure 4, are often enclosed in a glass or metal bulb, mounted on a base the same as the regular tubes and are known as a "Ballast" or "Ballast Tube".

PLATE SUPPLY

Starting at the lower wire of the "110 Volt Supply" of Figure 4, you will find a direct path to the plate of the rectifier tube. When the plate is positive, in respect to the cathode, current will pass through the tube, from plate to cathode which is therefore often considered as the supply positive.

From the rectifier cathode here, the circuit is through the choke which, with condensers C_9 and C_{10}, composes the filter that smooths out any variations of cathode current. From the choke, there is a connection to the screen grid of the a-f tube and, through the primary of the output transformer T_3 to the plate. Starting at the choke again, there is another path down, over to the left, up through R_6 to the detector plate and up through R_5 to the detector screen grid. Going further to the left, the circuit continues to the screen grid and, through the primary of T_2, to the plate of the r-f tube.

All of these circuits are completed to the other side of the supply circuit through the metal chassis or common return. For the r-f tube, the cathode connects to the return through the fixed resistance R_3 and variable resistance R_1 which controls the bias voltage. As a change of bias voltage varies the mutual conductance of a tube and therefore its effective amplification, R_1 acts as a volume control.

The detector tube circuits are completed from the cathode to the return through the bias resistor R_4. The same general plan is followed for the a-f or output tube, the cathode being connected to the return through the resistance R_8.

For all three tubes, the control grid circuit connects directly to the return while the plate and screen currents of each tube pass through its bias resistor. The voltage drops across these bias resistors, equal to the current times the resistance, make the cathode positive in respect to the return. As the grids connect directly to the return, they will be negative, in respect to the cathodes.

Each bias resistor has a condenser connected across it to maintain a more uniform voltage, as already explained in the earlier Lessons. In fact, the signal circuits of this receiver are the same as explained for similar units with other types of power supply.

Here, when connection is made to a 110 volt a-c circuit of any frequency, the heaters will operate properly, as already explained,and the rectifier will allow current only when the supply wire, to which the plate connects, is positive.

When connection is made to a 110 volt d-c supply, the attachment plug must be placed in the receptacle so that the positive side of the supply circuit connects directly to the rectifier plate. Under these conditions, there will be a continuous current from the rectifier plate to the cathode.

Keeping the action of the rectifier tube in mind, should the supply cord plug be inserted so that the plate connects to the negative side of the line,there will be no plate voltage although the tube filaments will burn normally. Thus you can understand why, with a d-c supply, it may be necessary to reverse the position of the supply cord plug in the power outlet in order to secure operation.

BATTERY OPERATION

To show you how circuits of this general type have been adapted for battery operation, in Figure 4 we have added a 5 prong socket which connects to the batteries through a plug. To provide proper operation, the a-f tube must now have a 6.3 volt and .3 amp. filament, the same as the r-f and detector tubes.

Instead of the type 25A6G of the former explanation we will assume the a-f tube is a type 38 which was popular for this purpose. For 117 volt operation with this tube, the total heater drop will be 6.3 + 6.3 + 6.3 + 12.6 for a total of 31.5 volts.

Resistance R_2 must now cause a drop of 117 - 31.5 = 85.5 volts which, at .3 ampere requires a value of 85.5 ÷ .3 = 285 ohms. Figuring as before, it will now be necessary for R_2 to dissipate 85.5 volts x .3 amp = 25.65 watts.

As both the plug and socket are shown from the top, when the plug is in position in the socket, the corresponding pins will be connected. Thus, the A+ battery wire, which connects to the top and left hand plug pin, will make contact with the top and left hand socket connections.

With this in mind, we can trace a circuit from ~~B+~~ A+ through the left hand pin of the socket, up and over through the a-f heater and back to the lower left socket contact which connects with A-. From the top contact of the socket, which also connects to A+, there is a circuit up and to the left, through the r-f heater and back to the lower left contact of the socket.

Starting from the top contact of the socket again, there is a circuit up and to the right, through the detector heater, back to the common return, and down to the lower right contact of the socket. As the A+ connects to the top and left contact of the socket and the A- connects to both lower contacts, the heaters of the r-f, det., and a-f tubes are in parallel across the A battery. The rectifier tube is not needed and therefore its heater is not connected.

The plate or "B" supply has its "+" connected to the right hand socket contact and its "-" connected to the lower contacts. Tracing from the right hand contact of the socket, there is a direct connection to the choke from which point, as already explained, current is supplied to all plate and screen circuits. These circuits are completed through the common return to the lower socket contacts and back to B-. Although not shown, a battery switch could be placed in the "A-B" wire of the battery connections.

Thus, with a 6 volt A battery and 90 volt B battery, the receiver will operate under practically the same conditions as when connected to a 110 volt supply. It may be well to mention here that, because the maximum a-c voltage is 1.4 times the effective value, the rectified a-c, when filtered, produces approximately the same d-c voltage as when a d-c power supply is used.

SIGNAL CIRCUITS

Checking briefly through the signal circuits, at the left you will find the antenna coil, T_1, the tuned secondary of which

is in the control grid circuit of the r-f tube. The signal is carried over to the detector grid through the r-f transformer T_2, the primary of which is in the plate circuit of the r-f tube and the tuned secondary in the detector grid circuit.

The detector is resistance-capacity coupled to the a-f or output tube which has output transformer T_3, in its plate circuit. The output transformer secondary connects to the speaker which is of the magnetic or Permanent Magnet type. In some receivers of this type, you will find the windings of a high impedance type speaker are connected in the plate circuit of the output tube thus eliminating the output transformer.

Tracing the input circuit, you will find the antenna connects directly to one end of the primary of T_1 and the circuit is completed to ground through condensers C_1 and C_2. Condenser C_1 is connected between the primary and the common return while C_2 is connected between the chassis, or common return, and the external or actual ground.

As you perhaps already know, the Electrical Code requires that lighting circuits be grounded on one side so that the voltage between the line and ground can never exceed the circuit voltage. In Figure 4, one side of the 110 volt supply connects directly to the chassis, or common return, and we will assume the plug has been inserted in the outlet so that this is the ungrounded or "hot" side of the supply circuit.

With an external ground properly made, there would thus be a short across the supply circuit unless condenser C_2 was in place. Also, it is quite common practice to use steam radiators and other similar grounded metal objects as an antenna and, unless C_1 were in place, again there would be a short across the power supply.

Equipment of this general type must always be arranged so that there is no direct connection between either of the power supply circuit wires and any external connection which may be grounded.

SIX TUBE SUPERHETERODYNE

To give you a further application of the a-c/d-c type of unit, for Figure 5 we show a 6 tube superheterodyne receiver which includes several features not included in the simpler TRF type receiver of Figure 4.

Checking on the tubes, you will find the first, or left hand one is a pentagrid converter which acts as a first detector and oscillator. This is followed by a pentode which acts as

an i-f amplifier, its output feeding into the diode plates of a duo-diode-triode.

This tube acts as the second detector, automatic volume control, (avc) and its triode section is the first audio amplifier. At the right there is a power pentode tube, and at the bottom the rectifier and ballast tubes.

You can trace the filament or heater circuit by starting at the upper wire of the power supply and passing through the "Ballast", "Rect.", "Output", "i-f", "1st Det.", "2nd Det.", tubes and back down to the lower power supply wire.

HIGH VOLTAGE CIRCUITS

For the high voltage, plate and screen circuits, you can start again at the upper wire of the power supply, go over to the right to the rectifier tube plates, across to the cathodes and up to the horizontal connections. To the right there is a direct path to the screen of the output tube and another path through the primary of the output transformer to the plate.

To the left, there is a path to the plate of the a-f tube, through R_{10} and through R_6 to the screen of the i-f tube and also through the primary of i-f T_2 to the plate. Also through the primary of i-f T_1 to the plate of the first detector, through R_2 to the screen grid and through the primary of the oscillator coil to grid No. 2.

All of these circuits are completed to ground through the cathodes of the various tubes and, from ground, the combined currents pass through R_4, R_9 and the speaker field to the lower power supply wire of our circuit. Here, the speaker field acts as the filter choke and together with condensers C_{13} and C_8, forms a condenser input filter. There is an error in the drawing and C_8 should be connected from ground to the rectifier cathodes instead of to the power supply.

SECOND DETECTOR

The second detector is of the diode type and its circuit is from the upper end of the secondary of i-f T_2 to the upper diode of Figure 5, across to the cathode and back through the volume control to the lower end of the secondary. The rectified signal voltage thus appears across the volume control potentiometer and is coupled to the grid of the a-f tube through condenser C_{10}. By adjusting the movable contact of this control, any desired part of the signal voltage may be applied to the a-f grid, thus regulating the volume.

AUTOMATIC VOLUME CONTROL

To maintain a more uniform output with various carrier voltages, there is an automatic volume control circuit through condenser C_{15} to the lower diode plate of the tube. The circuit here is from the diode plate to the cathode, to ground and back through R_4 and R_5 to the diode plate.

Like the control grids of the first detector and i-f amplifier tubes, the lower diode plate will be negatively biased by the drop across R_4 and thus, with no signal, there will be no current in R_5. However, when the signal voltage becomes greater than this bias, during each second alternation, the diode will be positive, in respect to the cathode, and there will be current in R_5.

The direction of this current will be from ground to the diode, and the voltage drop across R_5, caused by this current, will be positive at the grounded end and negative at the diode end. Checking back, you will find that R_5 is also in the control grid circuits of the first two tubes and any voltage drop across R_5 will be added to the bias voltage across R_4.

Thus, an increase of signal strength causes an increase of voltage across R_5 which, in turn, increases the bias on the control grids of the first two tubes. The action here is the same as explained for the volume control of Figure 1 but the bias is regulated by the signal strength and thus we have automatic volume control.

Remember here, the avc acts to maintain a constant signal level across the volume control which can be manually adjusted to allow any desired part of this voltage to reach the control grid circuit of the a-f tube.

As we have already explained, the avc circuit will not operate until the signal voltage is greater than the bias voltage on the diode plate and therefore the arrangement is known as "Delayed avc".

Resistance R_3 and condensers C_2 and C_7 act as a filter to prevent any signal frequencies from reaching the controlled grid circuits the same as R_7 and C_{11} in the grid circuit of the a-f tube.

The explanations of this Lesson complete the common type of Radio Receivers and we want you to notice particularly that about the only difference between the types is the matter of power supply. Practically all new sets employ the superheterodyne circuit and, if you understand its operation, and the various supplies we have explained, you are well on your way toward a good understanding of radio receivers.

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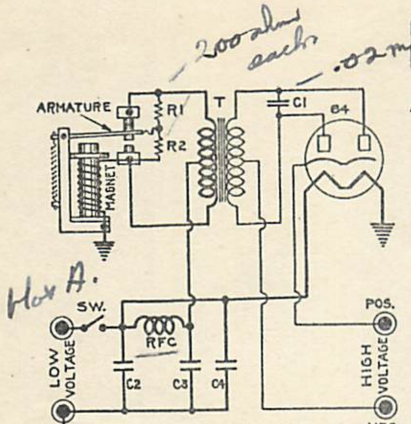

FIGURE 1

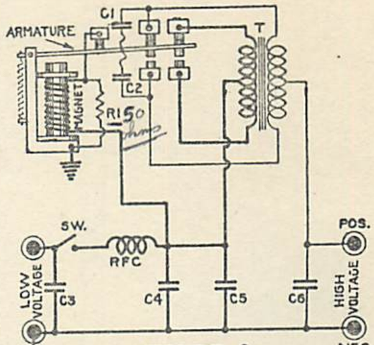

FIGURE 2

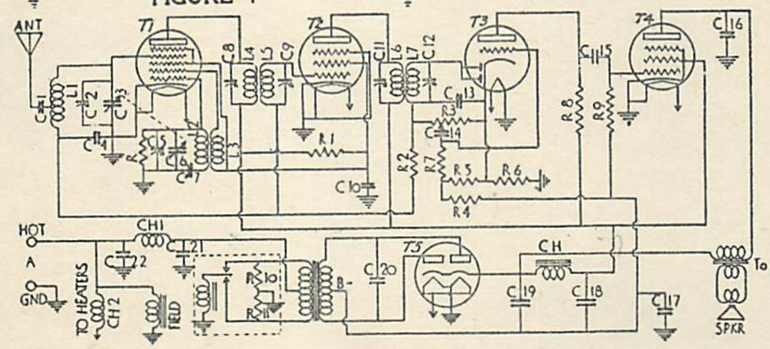

FIGURE 3

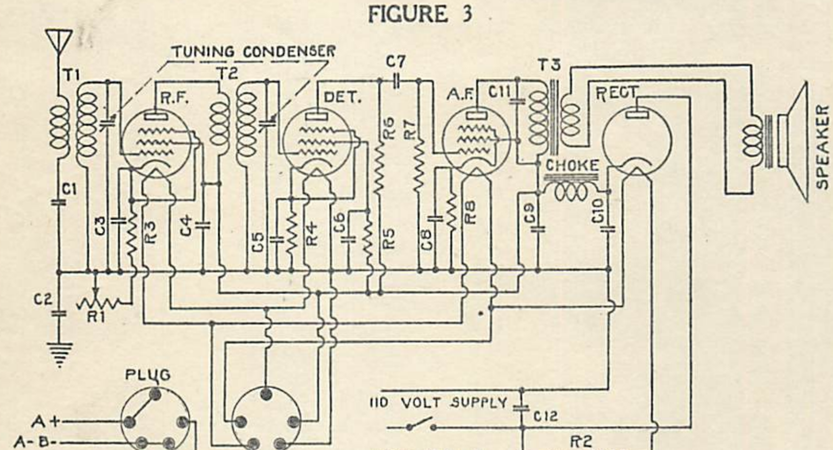

FIGURE 4

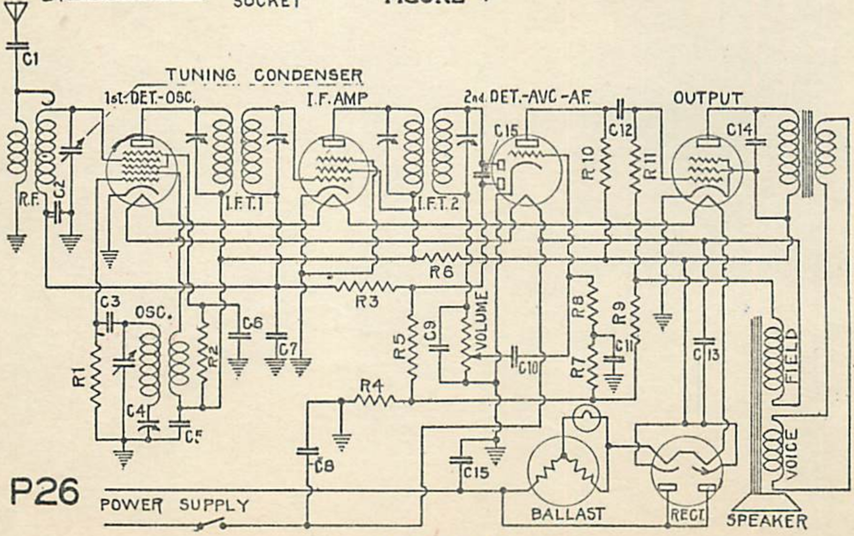

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FIGURE 5

QUESTIONS AND ANSWERS

1. What is the purpose of a "Vibrator" in an auto radio receiver?
The purpose of a vibrator in an auto radio receiver is to help change the battery d-c to a-c.

2. For an automobile radio receiver, what is meant by the "Hot A" terminal?
The "Hot A" terminal is the connection which is attached to the ungrounded side of the car battery.

3. What is a "Synchronous Vibrator"?
A synchronous vibrator is one which contains a second double pair of contacts to rectify the output of the power transformer secondary.

4. Why are resistors connected across the contacts of a simple vibrator?
Resistors connected across the contacts reduce the arc between the contacts and prolong their life.

5. To operate properly in series, what common characteristic must tube heaters have?
Heaters must require equal current to operate properly in series.

6. What is the advantage of a "Line Cord"?
A line cord provides better radiation for the series heater circuit resistor and keeps the heat out of the chassis.

7. What precaution must be taken when repairing a "Line Cord"?
A line cord must not be shortened, when repairs are made.

8. What precaution must be taken when a Universal Type Receiver is operated on a d-c lighting circuit?
The attachment plug must be placed in the receptacle so that the rectifier plate connects to the positive of the power supply.

9. How are the heaters of Figure 4 connected when using a battery supply?
The heaters are connected in parallel when a battery supply is used for Figure 4.

10. Why is it necessary to install a series condenser in the antenna and external ground circuits of a Universal type receiver?
Because the ordinary lighting circuit is grounded, the series condensers are necessary to prevent a short circuit when external connections are made.